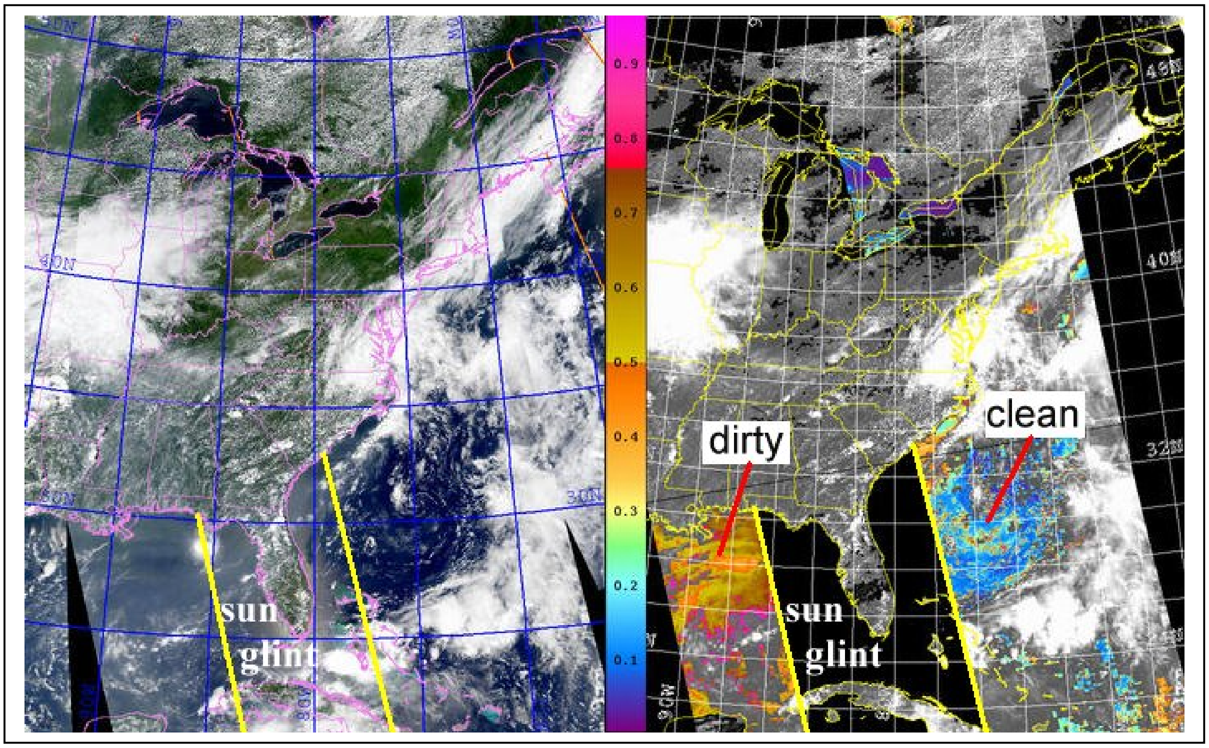
Satellite Product Tutorials:

Aerosol Optical Thickness



Above: The true color image on the left mimics what the human eye would "see" from space. The observer is somewhat limited in determining how clean or polluted the atmosphere appears over the region displayed. On the right, the aerosol optical thickness product greatly improves the interpretation of atmospheric turbidity over the water regions. As shown, the Gulf of Mexico has relatively high aerosol (polluted) content, while the cloud-free regions off the SE coast of the US are fairly clean. The annotated "sun glint" regions indicate strong mirror-like sunlight reflection off water. These regions present a problem to the aerosol optical thickness product and are removed (blacked out) from the imagery.

Why We're Interested…

Aerosols are small particles in the air that originate from a number of different natural and human-activity sources, including ocean spray, dust storms, fires, pollution from fossil fuel combustion. The aerosol optical thickness product can be used to provide an estimate of air quality over water. The Navy and Air Force are very interested in any measure of visibility (how far away an object can be detected), especially over the open water where such measurements are very sparse. For example, Navy aircraft carriers rely on adequate visibility depictions to plan operations using electronic and optical sensors that rely on reasonable atmospheric clarity. Pilots require reasonable slant range visibility for maneuverability, target location, and landing. In addition, weather forecast models and climotological studies are incorporating global aerosol products for better accuracy in assessing the global environment. Studies on climate change rely heavily upon aerosol content information.

How The Aerosol Optical Thickness is Created…

To isolate aerosol content in the satellite imagery, we must rely on satellite measurements and certain general assumptions about how aerosols are distributed throughout the atmosphere.

1) *Equation:* Radiative transfer theory describes interactions between the solar energy and the earth's atmosphere (including aerosols), and how the satellite then senses these interactions. A number of well-established assumptions are applied to simplify these relationships, and they are then used to calculate aerosol optical thickness. The information needed to solve this problem include the geometry between the sun, earth and satellite, the intensity of solar energy, the amount of reflected sunlight measured by the satellite sensor, and aerosol particle size and amount (aerosol size distribution) over the sensed region.
2) *Aerosol size distribution:* Since there are no sensors to measure directly the aerosol content over water, we base our estimates on satellite measurements from two visible channels having known sensitivity to atmospheric aerosols. Through these measurements we can estimate the characteristic size of aerosol particles over the region sensed by the satellite. Regions of cloud cover and sun glint (mentioned earlier) present challenges to this technique and are eliminated from consideration.
3) *Cloud, sun glint and land elimination:* Due to simplifying assumptions, the technique is only applicable to cloud-free, open water regions. In certain situations, the geometry between the sun and satellite produce a "mirror-

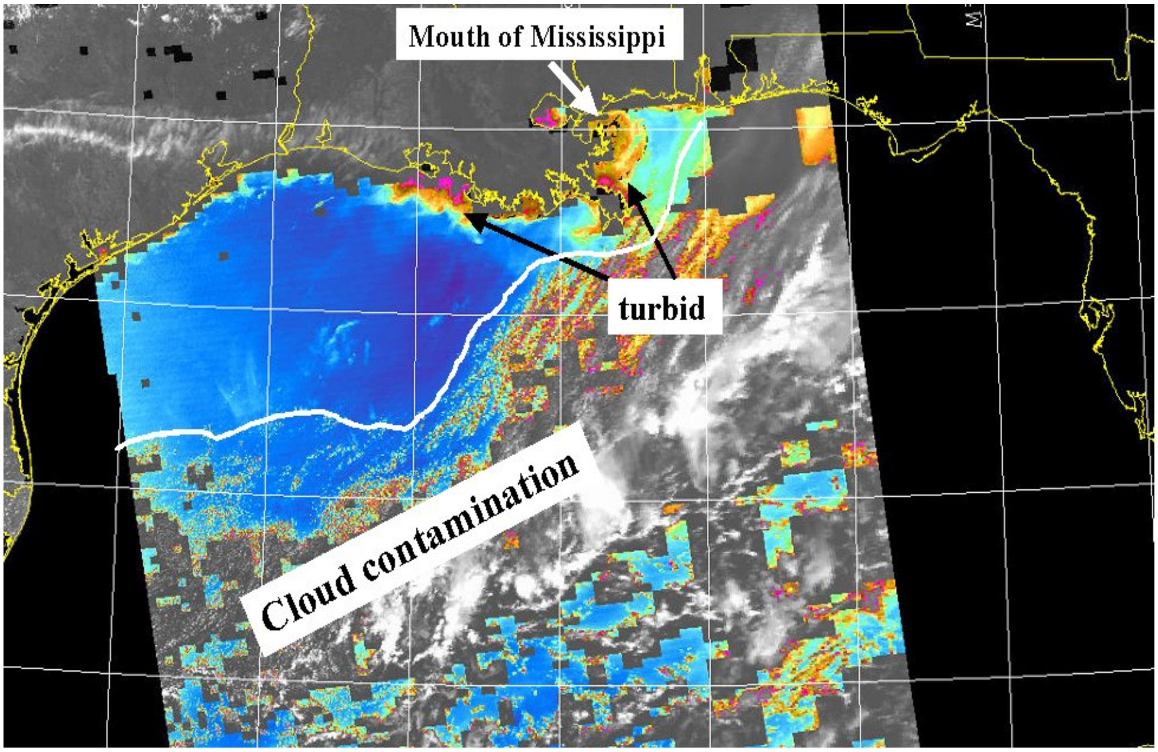
like" image of the sun off the water's surface, known as sun glint. These areas must also be removed from consideration.

How to Interpret…

The color scale attached to the product (see top figure) displays the amount of aerosols in the atmosphere. The higher the value, the greater impact there is on visibility. For example, if horizontal visibility on a clear day is 20 miles, then aerosol optical depths of (0.3, 0.7, and 1.4) would reduce this visibility to approximately (15, 10, and 5) miles, respectively. Blue colors indicate fairly clear conditions (low aerosol content) while the yellows and reds indicate high concentrations of atmospheric particles that are associated with reduced visibility. The "blacked out" regions represent sun glint. The product displays black-and-white visible imagery over land and in cloud contaminated regions.

What to look for: A rainbow of colors ranging from blue to pink over the water. Aerosol optical thickness patterns are fairly smooth, with dust fronts providing some color discontinuity. Scientists and military planners are often on the lookout for episodes of these dust plumes propagating over clearer bodies of water, i.e., a) African desert dust storms advancing toward the Caribbean, especially during the Spring and Summer months and b) Asian dust storms and industrial pollutants propagating over the Pacific Ocean, eventually impacting the western US during the spring months.

What to watch out for: Below is an image over the Gulf of Mexico that depicts some of the caveats to this product. Regions close to clouds (below the white line) are often contaminated, resulting in aerosol values that are significantly higher than surrounding background levels, and should be avoided. Coastal regions can also contribute to contamination. In addition, bodies of water such as the mouth of the Mississippi River (annotated below) often contain relatively high levels of water turbidity (sediment flowing in from in land rivers and streams) that can produce erroneously high estimates of aerosol in these regions.



Looking Toward the NPOESS Era…

The measurements required for calculating aerosol optical thickness via the technique shown here continue to be available operationally during the NPOESS era using the Visible Infrared Imaging Radiometer Suite (VIIRS). NPOESS-VIIRS will provide roughly a 4-hour refresh over mid-latitude open water regions during daytime hours. The high spatial resolution (370 meters, or just under ¼ mile "boxes") will enable improved depiction of aerosol content. The next-generation geostationary operational environmental satellite series, GOES-R will enable frequent refresh of these same products.

Did You Know…?

Our current understanding of the role played by aerosols in climate is very limited due to several competing effects. By reflecting sunlight, aerosols cool the planet. Through altering of cloud properties (more aerosols lead to more numerous, smaller cloud droplets which are less reflective), aerosols indirectly warm the planet. Finally, smaller cloud droplets can prolong cloud lifetimes—with impacts to climate change that are even less well understood.

Want to Learn More?

Naval Research Laboratory, Aerosol products web pages:
http://www.nrlmry.navy.mil/aerosol/Docs/npsaod.html
http://www.nrlmry.navy.mil/aerosol/#satelliteanalyses
http://www.nrlmry.navy.mil/flambe/

Science papers:

Durkee, P. A., K. E. Nielsen, P. J. Smith, P. B. Russell, B. Schmid, J. M. Livingston, B. N. Holben, C. Tomasi, V. Vitale, D. Collins, R. C. Flagan, J. H. Seinfeld, K. J. Noone, E. Öström, S. Gasso, D. Hegg, L. M. Russell, T. S. Bates and P. K. Quinn, 1999: Regional aerosol optical depth characteristics from satellite observations: ACE-1, TARFOX and ACE-2 results. *Tellus,* **51B**, 1-14.

Kuciauskas, A.P., P.A. Durkee, D.L. Westphal, 2003: Aerosol optical depth analysis with NOAA Goes and POES in the western Atlantic. 12th Conference on Satellite Meteorology and Oceanography, Amer. Meteo. Soc., 9-13 February 2003, Long Beach, CA.

Smith, P. J., 1998: Remote measurement of aerosol optical properties using the NOAA POES AVHRR during ACE-1, TARFOX, and ACE-2. M.S. Thesis, Naval Postgraduate School, Monterey, CA, 58 pp.

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